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National Science and Technology Monitoring and Alerting Systems

A Report Prepared for
The Korea Institute of Science and Technology Information

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EXECUTIVE SUMMARY

National S&T Monitoring and Alerting (M&A) Systems

The overall goal of the project is to study the international state of the art in systematic, data-based systems for monitoring and alerting for emerging technologies, and to develop concepts for a monitoring and alerting (M&A) system for the Korean context in the light of international experience.

The project defines *S&T monitoring* as the systematic scan of an environment for either opportunities or threats above a threshold level of significance. It defines *S&T alerting* as reporting to a client that such an opportunity or threat exists, perhaps triggering further analysis or action. S&T monitoring and alerting are part of a family of techniques that are used in S&T strategic intelligence, that is, the gathering and analyzing of S&T information as an input to decision making.

As part of this project, TPAC consulted with a wide range of international experts in S&T strategic intelligence. Among the many who responded, none identified an existing national-level S&T monitoring and alerting system. The closest equivalents at national level are national S&T indicator systems, which operate at very broad levels of aggregation and do not identify emerging technologies.

S&T monitoring and alerting functions, however, are carried out within many private firms, although they may not be named with these exact terms. Air Products provides an example (Brenner 2005). Within that firm, a special unit serves the company by providing a mechanism for identifying the needs of users within the company and monitoring information sources that give very early signals of developments of interest. Daily alerts are distributed by email, and the unit reports a success rate of about 30% in identifying developments that users find new and worth following up. This unit within Air Products uses its specialized skills to provide and stimulate a number of other strategic intelligence functions for the company.

Closer to national level, the project identified several government agencies that perform analyses that contribute to strategic intelligence, but only in specific areas and for specific clients within government. For example, the Brazilian Center for Strategic Management and Studies has used forecasting, road mapping, assessment and foresight to produce studies of areas such as biomass energy, mineral technologies, health, water quality, and the chemical sector.

In both private firms and government agencies, the process of monitoring and analysis begins by setting boundaries for the search for information using systematic tools to assess user needs. Once such boundaries are set, these organizations typically carry out specialized analyses, using a wide variety of available tools. For regular alerting, computerized literature-retrieval systems can provide periodic automatic updates on publications in specific areas of interest for clients, but such searches do not evaluate the information retrieved.

A national-level monitoring and alerting system thus poses a unique and original challenge. Since systems with similar functions exist in private firms and government agencies, a national system should not duplicate the functions that can be carried out at that level. Different monitoring and alerting questions arise at national level, industry level, and firm level, and a system could encompass analysis for all three. To help specific organizations within the national system, such as universities, government research institutes, or private firms, complementary tools and training could be provided to help these organizations develop their own skills in strategic intelligence and train them to monitor and evaluate developments in technical areas specific to their interests.

The national level of the system should concentrate on identifying major developments that are likely to have impacts across a broad range of actors in the national system. The system could include a characterization of the country's existing S&T capabilities, including major competitors, to help identify areas where opportunities and threats are most immediate. It could then include more fine-grained monitoring in those areas, and broader-scale monitoring of where national capabilities are located in the overall landscape of both science and technology. The analysis would need to be dynamic in its characterization of national capabilities as well as capturing change in the environment. In providing such a perspective, the techniques for mapping broad scientific terrains could complement existing tools for more detailed analysis.

CHAPTER ONE: PROBLEM AND CONCEPTS

The global knowledge environment is turbulent. New research areas emerge continually from the base of incremental knowledge change in scientific disciplines. New technologies emerge, and even whole families of technologies, pushed forward by firms seeking technological advantage in worldwide competition. Some new technological capabilities arise directly from research frontiers, and some research frontiers become suddenly possible because of new techniques. Finally, both research frontiers and emerging technologies find new applications continually, bringing into reach products and public goods that were previously inaccessible.

In the midst of this environment of continuous change, national science and technology leaders are trying to accomplish a number of goals, including

- Providing the research base for economic growth for their countries;
- Positioning their countries with regard to new science-based industries;
- Seeking new technologies to produce public infrastructure and public goods more efficiently, in areas like energy, environment, and health;
- Ensuring balance and excellence in the public research portfolio, so that their countries are prepared to take advantage of the next unexpected development in the global knowledge environment.

A science and technology (S&T) monitoring and alerting (M&A) system can help national S&T leaders with these tasks by providing systematic information to inform their decisions. According to Porter and Cunningham (2005), an M&A system facilitates innovation by supporting and informing decisions on strategy and priorities. It provides the capability to profile research domains, map relationships, discern overall trends, track internal and external technological capabilities, and anticipate potential outcomes. Because an M&A system draws on global data sets generated for other purposes, it can provide objective data and analysis to supplement the wisdom, judgment, and expertise of government's technical advisors. It provides access to huge quantities of information but distills what they say into messages that are important to a particular research and technology system at a particular point in time.

The system itself, however, must be tailored to the needs of decision makers. It should help decision makers see where national efforts fit into the global context; identify major developments outside the country that could be significant inside; and report on developments related to the country's current research and development (R&D) efforts. The special strengths of a national M&A system are its ability to track changes quickly at a detailed technical level and its ability to link that information to the specific technical needs of national institutions. Technology is widely recognized as a risky endeavor, and an M&A system can help to identify competitors and trends that can disrupt economic success for firms and for countries. These capabilities add significantly to the strategic intelligence capacity of any national government.

This report is intended to help the Korea Institute of Science and Technology Information develop a national M&A system for Korea, by doing two things:

- Surveying the international state of the art in systematic, data-based systems for monitoring and alerting with regard to emerging research areas and technologies;
- Developing options for an M&A system for the Korean context.

This project draws on the findings of last year's collaborative research with KISTI (Cozzens et al. 2005). In that project, we developed a working definition of emerging technologies, reviewed the range of systematic data sources available to study them, and discussed the strengths and weaknesses of various techniques for analyzing that data to identify emerging structures.

In this project, we first reviewed the literature on S&T strategic intelligence to put the idea of the national M&A system in context of S&T policy issues. The results of this work appear in the remainder of this chapter. Next, we looked for examples of M&A systems in public and private organizations; these appear in Chapter Two. Finally, we drew on both these information sources in developing our list of options for KISTI, reported in Chapter Three.

Technological Innovation

Technological innovation, defined as a process by which ideas are generated, developed and transformed into new products, processes and services with marketable value, has been modeled in different ways to achieve actionable technological intelligence practices, according to Porter and Cunningham (2005). For some time now, technological innovation has been portrayed as resulting from R&D acting as the essential push that prompts new product development, which the marketplace then accepts (technology push model). In a similarly linear way, while identifying the 'trigger' at the other end of the innovation process continuum, technological innovation is portrayed as response to market demands, where the main influence begins at the customer end (market pull model). A more sophisticated, but still essentially linear, view of the innovation process is the so-called chain link model which acknowledges that influences from technology and the marketplace iterate in multidirectional ways. A common denominator of these models, Porter and Cunningham (2005) write, is that a single organization generates new technology and takes it to the market.

A newer family of innovation process models attend to the interactions among institutions within what is commonly called an 'innovation system'. These models -- which include national innovation systems, regional innovation systems, networks, clusters, and socio-technical systems -- assume that actors of diverse nature (researchers, entrepreneurs, policymakers, policy implementers, etc.), operate in a system of competitive and collaborative relationships. As Porter and Cunningham (2005) point out, technological change results from the confluence of efforts of multiple actors -- laboratories, firms, universities, government agencies, customers, and other stakeholders. Such frameworks view the innovation process in terms of 'knowledge networks.' Four "I-levels" of networking activity are identified as vital to innovation processes:

1. **I**deas compete and become interlinked
2. **I**nnovators select, vary, and propagate the successful ideas

3. **I**nstitutions construct teams of scientists and technologists (innovators) and cooperate and compete with other institutions
4. **I**nitiators fund the R&D activities of institutions.

As Porter and Cunningham (2005) describe, ideas are tested constantly against the facts of the real world and needs of the customer, making the customer critical to successful innovations. New products build on a match of new ideas to existing competencies. Successful products stem from the intersection of customer need and technological competencies. Institutions that are successful in new product development must understand their customer, building upon the existing customer base and learning about new customers, or formerly unrecognized needs of old customers.

The networking interchanges provide the essential conditions for the operation of a Monitoring and Alerting System, according to Porter and Cunningham (2005). The various exchanges of science and technology information effectively document knowledge at all four levels. Indeed, scientists and technologists produce findings; institutions provide incentives to make those findings visible; the ideas used by the innovators are reflected in their publications and patents; and the relationships among innovators, between them and the various institutions, between these institutions and the initiators, and between all these actors and their markets can also be discerned by monitoring their performance on the ground. Hence, analyzing patterns of scientific projects, reports, publications, patents, and product announcements - as by-products of the exploration and exploitation of science and technology – can provide a lot of insight into actual practices leading to technological innovation.

An M&AS produces information on “who’s doing what”. Tracking ideas and individuals provides vital intelligence that serves various innovators and technology managers, as Porter and Cunningham (2005) point out. Too often, researchers and developers reproduce solutions that are known in other disciplines or industries. A successful innovation reflects in authentically new products, processes, and services. The intellectual property may be protected through patenting. Academic innovators contribute to public knowledge mainly through publication of journal articles or conference papers. Thus, industrial and academic innovators are avid producers -- and consumers -- of science and technology information. They are both part and parcel of an M&AS.

Locating the S&T information needed to inform R&D decision making presents a challenge. Porter and Cunningham (2005) note that innovations are increasingly dependent on new science, and new science such as nanotechnology or biotechnology is increasingly multidisciplinary and therefore distributed across multiple fields and sectors. Indeed, the nature of emerging technologies of interest is itself changing. There are corresponding challenges in identifying threats and abating the attendant risks. Cross-disciplinary and cross-sector knowledge awareness and integration is mandatory today. An M&A system can play a major role in integrating disparate information sources into usable technical intelligence.

An M&A system can help address the following challenges, according to Porter and Cunningham (2005):

- Innovation is essential, but risk management practices are needed.

- Innovation necessitates identifying both individuals and institutions with complementary knowledge.
- Knowledge creates spillovers; protecting knowledge as well as accessing all publicly available knowledge is crucial to success.
- Knowledge is often specialized in character, yet it must be synthesized and integrated by other non-specialists.
- Too many organizations fail to identify relevant external R&D
- Innovation draws on knowledge of customers and the market place.
- Science-based industries are making very direct connections between basic knowledge and the marketplace.

These challenges imply that organizations that track science and technology gain significant competitive advantages over those who do not. These lessons can also apply at national level.

S&T strategic intelligence

National M&A systems are part of a family of processes that produce "science and technology strategic intelligence" (STSI). These processes gather and analyze S&T information as an input to decision making in private firms, universities, public research institutions, and governments, at regional, national, or international level. S&T strategic intelligence has been particularly well developed in Europe, where the European Commission's Institute for Prospective Technological Studies has provided leadership. Kuhlmann (2006) describes strategic intelligence as the systematic analysis that informs policy discussions. It includes

- "... a set of sources of information - often distributed and heterogeneous
- explorative/empirical as well as analytical (theoretical, heuristic, methodological) tools
- employed to produce useful "multi-perspective" insight in the actual or potential costs and effects of public or private policy and management, 'injected' and 'digested' in the macro- or micro-political arena."

He explains that "well known strategic intelligence tools are evaluation studies, performance measurement, benchmarking initiatives, foresight exercises, or technology assessment (TA)." The tools are heterogeneous because they support a wide range of policy choices, as show in Table 1.1.

Table 1.1

Innovation system success factors and policy support

(from Kuhlmann 2006)

Factor	**Public policy**
Entrepreneurial activities	**Corporate governance; insolvency legislation; education**
Knowledge creation	**Funding of basic and applied research; (higher) education and training**
Knowledge diffusion through networks	**Support for R&D and innovation networks (industry, academia, et al.) and clusters; multi-actor programmes; support for knowledge infrastructures (e.g. patent data bases)**
Guidance of the search	**Science and technology foresight exercises; communication platforms/fora for industry, academia, societal organisations and public policy**
Market formation	**Regulatory frameworks for technical standards and norms; ethical regulation; Intellectual property rights (IPR); et al.**
Resources mobilization	**Thematic or sectoral profiling of public investment in science, R&D, and education**
Creation of legitimacy/ counteract resistance to change	**S/T foresight exercises; communication platforms/fora; maintaining policy networks (e.g. multilevel cooperation across regions, nations and trans national levels); fostering institutional adaptation and change**

The family of techniques that support S&T strategic intelligence range in data source from quite qualitative (e.g., press reports on business developments, interviews with firms, or presentations at professional meetings) to sophisticated analysis of quantitative data sources, including grants, publications, and patents. In the private sector, these activities are often called "technological intelligence" or "competitive intelligence." They are oriented towards identifying competitors for technologies being developed in the firm and opportunities for new business from emerging technologies.

In the public sector, perhaps the most prominent strategic intelligence process is a process called "foresight." Although precursors of Foresight can be traced back as far as the 1970s, the approach has been systematized over the last decade, and is now used regularly in many countries in Europe, Latin America, Africa, and Asia. Foresight presents quantitative information to panels of stakeholders, drawn broadly from among the groups in society with an interest in a particular technology, industry, or field of research. The group then considers and reacts to different possible scenarios for the development of that area. Foresight practitioners report that the process of compiling information and bringing together stakeholders is the key benefit. The panels are sometimes asked to make recommendations, but these are sometimes less influential than the community- and consensus-building that results from the process. Foresight exercises are often used to identify key technologies or set priorities within fields of research.

Similarly, experts in strategic intelligence processes report that while the analysis of systematic data is crucial to effective strategic intelligence, the best STSI combines objective with judgmental information. The organization and presentation of the objective information is also crucial, and such information must be introduced at the right time in relation to the decision to have an impact.

It is important to understand the difference between modern strategic intelligence activities and more traditional national science and technology indicators, gathered and reported by all OECD countries and many others as well. National S&T indicators focus on counting the inputs to a country's science and technology efforts, especially trained people and funding streams. They usually gather and report this information in categories that were set in the 1960s by OECD working groups, categories that indicators groups have been reluctant to change for fear of disrupting their long time series of data. The categories therefore do not reflect the changing structure of science and technology as the results of more recent strategic intelligence analytic techniques do. Output and results data in S&T indicator systems are usually reported in the same categories as inputs to allow comparison, and therefore show the same problem of inflexibility with regard to the changing structures of science. S&T indicator systems usually include measures of quality, to indicate the strength or weakness of national science and engineering efforts at an aggregate level, or by broad fields.

In contrast, the indicators produced in S&T strategic intelligence processes provide information at a more detailed technical level. The more flexible analytic techniques of STSI reflect the changing structures of science and technology, and can track local institutions and their competition in that structure. They are therefore capable of providing information on opportunities and threats that are specifically related to activities in a national innovation system. They can thus produce information on "advantage" and "application" rather than only on strength and weakness.

Basic concepts

The design of a national M&A system draws on several basic concepts, which it is useful to review at this early stage of our report. The first is the idea of emergence, whether in science or technology.

Emerging research areas in science form around a critical finding, a new idea, or a fresh opportunity presented by new instrumentation. One or more research teams publish the first findings in the new area, other teams are attracted to the opportunities there and the number of publications builds quickly. Sometimes such an area develops into a new, established subfield, with its own journals and sections of professional meetings and abstracting services. Other times, the intellectual space is fully explored and the researchers move on to explore other new ideas. These emerging research areas were first discussed by Derek Price in and explored by sociologists of science such as Diana Crane and Nicholas Mullins. In the 1970s, Henry Small and Belver Griffith developed a literature-based method for identifying such areas using citation data. This method has been incorporated in Thomson Scientific's "research fronts" data base. These areas can also be identified using the clustering of keywords. Analysts typically look in the published research literature for such indicators.

An emerging technology, as we reviewed in our report last year, is one that is new, science based, and perceived as having commercial potential. The combination of newness and commercial potential tends to produce the same kind of spurt of activity as is seen in emerging research areas. The term "emerging technology" is not generally used for new opportunities that are being pursued with existing or traditional techniques based on new insights or combinations, but rather refers to opportunities that arise from the advance of scientific knowledge. Sometimes an emerging research area will spawn one or more emerging technologies; but not all emerging research areas will do so, and some emerging technologies will be based on older science, not the latest research front.

Analysts usually look for the signals of emerging technologies in patents, which stake a claim to the commercial potential that someone sees in an area. As with publications, just one patent application is not a sufficient signal of an emerging technology; rather, the analyst needs to look for a cluster of patents, including concentrations of citations from new patent applications to some older, base patent. Connections to bodies of scientific knowledge can be observed in citations from patents to publications. As we noted in our report last year, not all important advances in technology can be protected with patents, so patent indicators give only a partial view of the emerging structure of technology-based economic opportunities. But they are still the best source available.

For the purposes of this project, TPAC needed a working definition of both "monitoring" and "alerting." We understand monitoring to be the systematic checking of a defined environment for opportunities or threats above a threshold level of significance. We defined "alerting" as reporting to a client that such an opportunity or threat exists, for possible action on the part of the client.[1]

An example of a monitoring system is the network of seismic sensors that regularly track ground vibrations. These sensors measure the magnitude of activity and thus can signal the difference between a truck rolling by on the highway from a pre-earthquake tremor or the earthquake itself. If the earthquake happens, and happens near a major body of water, the monitoring system can send a report to coastal populations on the other side to move back from the coast to avoid a tsunami. Another example is the instrument that monitors the blood sugar level of a diabetic on a near-continuous basis. When the instrument determines that blood sugar has gone out of the normal range, it sends a report to the wearer to indicate whether the level is low or high. The diabetic can then add either sugar or insulin to the bloodstream, to bring the level back into the normal range.

In both examples, the monitoring system includes both measurement of something important and information on what is in the normal range and what is outside of it. The monitoring system itself does not determine action, but makes a report to a decision maker about a situation that probably calls for action.

[1] These may or may not be the definitions KISTI wishes to adopt in its own development of the national M&A system.

Applications in research policy

A national M&A system can be useful in several different areas of science and technology policy. This section discusses applications in research policy, that is, government actions to stimulate the production of new knowledge, including both fundamental and strategic research. The next section discusses applications in innovation policy, that is, government actions to stimulate the development of new products or processes in either the public or private sector.

National governments around the world invest in research and development (R&D) activities, although they do so at different levels and with different balances among common public goals. According to the most recent data announced in August 2006 by the Ministry of Science and Technology (MOST), Korea as a nation spent 24,154,400 million Korean Won on R&D in 2005. This amount is roughly 25.4 billion in U.S. dollars. Among these total national R&D expenditures over $25 billion, the Korean government spent about $6.2 billion, and Korean firms spent an additional $19 billion. Korea's national R&D investment was shared among universities (9.9%), government research institutes (13.2%), and private firms (76.9%).

According to the same statistics announced by MOST this year, 15.3% of Korea's investment in 2005 is considered "basic research," that is, research that is not tied to specific problems to be solved or technologies to be developed. One complement to "basic" or fundamental research is "strategic" research, that is, fundamental research undertaken in areas that are directly relevant to solving national problems or developing new technologies in the country's industries. Another complementary form of research is "applied research," that is, research that draws on existing knowledge to solve specific problems or develop technologies, without creating any fundamentally new insights.

A national M&A system can help in evaluating and setting priorities for a country's research portfolio, by providing data relevant to the following questions, phrased in terms of Korea:

- Are Korea's researchers participating in the emerging research areas of world science? Are they major or minor contributors?
- Are there emerging areas of world science where Korea's researchers are not participating? Policy makers would need to determine whether these "missing" areas are important to Korea's national goals or not.
- For areas where Korea's universities and government research institutes are doing strategic research on Korea's national goals, what other institutions are active in those areas? Are Korea's research institutions leading or lagging in those areas? Are there major new developments connected to those areas that Korean researchers should become aware of?
- In strategic and applied research areas, are there signs of cooperation between universities, government research institutions, and the private firms that would turn their innovations into commercially viable products? Do Korean research institutions collaborate with industry in these areas at similar rates to those in other countries?

Note that in comparison with national S&T indicator systems, the national M&A system would provide this information at a more detailed technical level, the level of research fronts. It would thus provide more focused information for setting national priorities for new research thrusts.

Applications in innovation policy

National governments want their economies to be successful in a world of technological change. Many of them are therefore considering actions to create the right conditions for private sector innovation; ensure the flow of trained people necessary for technology-based firms; and stimulate technological change in firms. In working towards these goals, governments face a number of challenges. Some are organizational, such as getting attention from researchers and gaining the cooperation of firms. Some are institutional. These policy makers must ask themselves, "What are the right policies and programs to use? Which ones will work in our context?" Finally, national governments face the challenge of technological change, creating a constantly changing competitive environment. This is the challenge that a national M&A system can help them to address.

The best way for a nation to succeed in a world of technological change is to get out in front in the innovation process. Although countries do encourage incremental innovations, they particularly want to make their countries the kind of places where the next breakthrough happens, so that they can be at the leading edge of a new technological wave. These processes focus on creating opportunities.

At the same time, countries must be aware of technological threats, that is, changes that happen in other places and that lead to loss of competitive edge. Countries want to be able to recognize important changes of this sort early so that they can respond to them appropriately. This is the task that a national M&A system can help with, by providing data relevant to questions like the following (phrased for Korea):

- What are the key technologies in use in Korea's major national industries? Are there other technologies being developed outside Korea that might displace these?
- Who are the major competitors to Korea's main technology-based firms? What technologies are they developing? This information could be used to make judgments about whether those technologies pose a threat to the current markets of Korean firms.
- Are there major developments in world technology that could develop into new industries that would displace current Korean businesses? Does Korean have the right people and knowledge to track those developments and incorporate them into Korean industry?
- What are Korea's core technological competences? What opportunities visible in global technology use these competencies particularly strongly? This information could be used to help set priorities for public research investments that would complement the development of some of those areas.

Summary

M&A systems are part of a family of techniques called "S&T strategic intelligence." A national M&A system would provide systematic data on national S&T

capabilities and competition at a more detailed technical level than traditional S&T indicator systems. The data provided could inform decisions in both research and innovation policy. To perform these functions, the system would need the capability both to scan broadly across world science and technology for developments that could be relevant in the Korean context and to focus on what is happening in the environments of national institutions and industries with regard to their specific capabilities and problem areas. The next chapter describes organizations and processes that provide these capabilities in other countries.

CHAPTER TWO: THE STATE OF THE ART

Our search for existing national M&A systems did not produce any examples at national level, although we searched widely among relevant colleague groups and in the literature. The examples we provide here therefore represent the strategic intelligence activities of individual organizations. Most organizations that use strategic/ competitive intelligence do not describe the details of their work in published sources, since they produce proprietary information. However, certain patterns are visible across the examples, even without the details. One is that user interaction is crucial in identifying what is important and what to focus on in a strategic intelligence effort. Another is that the studies mostly focus on or try to identify specific technological areas, not scan broadly as a national M&A system would need to do.

Sources of information

As a part of our work, we conducted a general internet search to find any relevant systems developed for the purpose of S&T monitoring and alerting, but did not locate an example of such a system. The search showed that the term "monitoring and alerting (system)" is not used in association with the term "S&T" and is mostly associated with with emergency management of tsunamis, presumably due to increased interest after the 2004 tragedy. The term "monitoring and alerting system" is mainly associated in the literature with the following terms: network; information security; national security; environment; pollution; medical. Similarly, a somewhat different search term "monitoring technological change" is most often combined with the following terms: forest; climate (change); environmental.

We also conducted a series of interviews and email contacts with professionals in S&T competitive intelligence, seeking to tap into their experience to locate the elements that should be incorporated into a national system. Alan Porter made these contacts in connection with the Annual Meeting of the Society of Competitive Intelligence Professionals (SCIP) and through contacts with PIUG – the Patent Information Users Group meeting. Both these groups emphasize private sector applications of the M&A concept. With this group, it was a real challenge to focus effectively on pertinent M&AS efforts. Toward this end, we directed the interviews towards structured, literature-based monitoring and alerting efforts. We were especially interested in M&A systems that were already being used in firms, seeking to know what was being done and how. The most compelling activities identified are described later in the chapter.

Our approach to follow up on promising possibilities has largely been via e-mail. Where we have personal contacts, we ask them about their activities. Where it seems appropriate, we ask about their knowledge of others performing structured, literature-based monitoring and alerting efforts.[2] Among those contacted:

- Ron Kostoff, US ONR
- Gilda Massari, CGEE

[2] For instance, here are questions posed to Ron Kostoff at the Office of Naval Research: 1. Do you consider ONR as having a structured, literature-based technology monitoring system in place? 2. Do you know of any other organizations that regularly perform structured, literature-based technology monitoring at a national level?

- Gregory Fruchet, NRC-Canada
- Jim Ramsbotham, small firm working with the US Department of Defense
- Merrill Brenner, Air Products & Chemicals
- Dick Klavans (in person)
- Tony Trippe (in person)
- Luke Georghiou, PREST, Manchester
- Brad Ashton, CTC
- Donghua Zhu, Beijing Institute of Technology [building a patent analysis and technology monitoring capability]
- Paul Frey, Search Technology [network of contacts doing S&T tech mining]
- Fabiana Scapolo, IPTS
- Tony Breitzman, 1790 Analytics
- Jay Papp, SCIP Conference

Findings from Personal Contacts

We asked many of these contacts a question like: *Do you know of any other organizations that regularly perform structured, literature-based technology monitoring at a national level?* The answers were generally negative. For instance, Jim Ramsbotham said:

> Honestly, no. None that do it with any degree of critical assessment. Everyone (except us that I know of) simply serves as a clearing house for the results of data mining or for information pushed from various proponents of technology.

Other colleagues also did not consider their work as a structured, literature-based M&A system (e.g., Fruchet at NRC-Canada; Kostoff at US ONR), nor did they suggest others who have such systems in place. However, they did describe a variety of interesting approaches and sources that could prove valuable as KISTI designs its M&AS.

The **European Foresight Monitoring Network** has reviewed global technology foresight activities [http://www.efmn.info/pdf/EFMN_Mapping_Report_2005.pdf]. In particular they run an interesting tabulation on the use of 21 methods in foresight exercises. Most relevant to M&AS interests, the use of bibliometrics is relatively limited See the second to last picture at www.efmn.info/mapping.shtml?s=82CF46D1-7D6610001653-7B7A .

IPTS (The Institute for Prospective Technological Studies) engages in activities generally oriented to tracking and analyzing technological change. Here's a piece of a current (June, 2006) call: EPIS06 is called to develop two types of activities so as to achieve the stated goals:

- To develop an on-going monitoring capability on global and European ICT trends and future thinking (vision-building)
- To as early as possible highlight fast growing areas with potential for disruption or significant technological/application impacts.

In September, 2006, IPTS hosted the second seminar on "Future-oriented Technology Analyses" (FTA) – see http://www.jrc.es/home/pages/home.htm]. That said, they do not have an ongoing structured, literature-based M&A system.

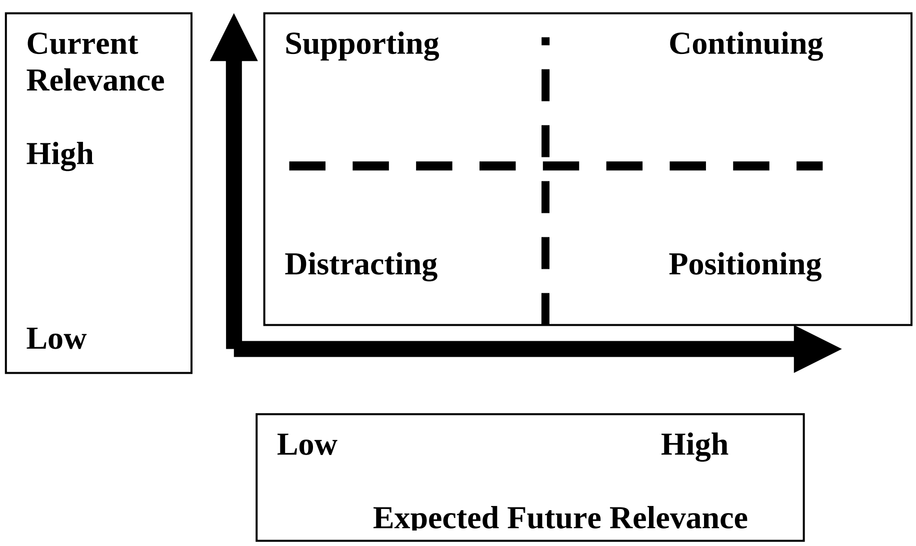
CGEE is a Brazilian organization wtih strong ties to the national government S&T ministry to advance strategic planning, including interesting S&T M&A work. We describe their efforts later in the chapter. However, when asked, they did not consider their activities as structured monitoring. They are considering establishing a possible "observatory" and would be pleased to discuss ideas with KISTI.

Jay Papp has helped a number of companies set up technology scouting systems over the years, including Astra-Zeneca and Xerox. He defines technology scouting as:

- An organized approach to looking externally for technology that can be adapted to meet the tactical or strategic development needs of an organization

Jay suggests that the M&AS should start with "problem research" – start with the key users' needs as the analyst understands them. He advises analysts to listen to what users say they need, but go beyond this, too. Scouting should cross boundaries, he maintains. Solutions in other sectors can provide lessons with analogy value to a target sector application. He provides a helpful screening matrix:

Figure 2.1. Scouting Matrix



Supporting technologies are highly relevant today, but probably less so in the future. Conversely, positioning technologies are anticipated to become considerably more important to one's interests in the future than they are now. Continuing technologies remain vital; distracting technologies are not salient.

Papp goes on to suggest an evaluation approach. Consider two components:

1) productivity = change/unit of investment

2) leverage = impact/change

If a given technological change offers little leverage, it does not matter much for the client's interests. This implies we need to understand the emerging socio-economic needs (of our nation or organization) to assess how extensively these would be impacted by particular emerging technology induced changes. Furthermore, Papp advises, consider technological change vis-à-vis thresholds. If the current technology is capable of achieving the target need, then it will be tough for an alternative technology to break through.

Tony Trippe, Chemical Abstracts Services (CAS) notes that companies such as Air Products and Exxon-Mobil have text mining systems in place. While he was at P&G, they analyzed technical data and assessed a range of tools for text and numerical data mining. He offered a case illustration. Vertex Pharmaceuticals examines which companies cite their patents and papers most heavily. They go on then to assess those companies' interests. Do they work the same or additional (new to Vertex) research areas? This M&AS helps spot areas where Vertex itself is not active.

Brad Ashton, Concurrent Technologies (CTC) offers a technology scouting service. This helps organizations find existing and emerging technologies, along with leading-edge organizations. We have a description of their 5-step scouting process. This includes multi-source searching and screening to address the issues of interest. They can go on to assess relative merits of alternative technologies thereby discovered.

Tony Breitzman, 1790 Analytics (a small firm that develops quantitative indicators based on patent and publication analyses), noted their "hot spots" analyses. This is a method for identifying important, high impact technologies. To this end, Thomas and Breitzman's paper, "A method for identifying hot patents and linking them to government funded scientific research" [to appear in *Research Evaluation*] discusses a patent citation analysis technique designed to identify patents whose impact on recent technology developments is particularly strong. These patents are defined as hot patents. This paper also examines links between hot patents and scientific research funded by different government agencies. Results indicate that patents that cite scientific papers funded by government agencies are more likely to become hot patents than patents that do not have such a citation link to publicly funded scientific research. Their results also reveal how hot patents can be used to demonstrate the geographical breadth of influence of an individual government agency's funding of science.

Breitzman published an article on the idea of hot patents in 2003 (referred to at that time as 'hotspots') as a new method for identifying patents whose impact on recent technological developments is particularly strong. In this process, he defined two types of highly cited patents. While both types of patents have had a strong technological impact, the difference between them lies in the pattern of citations they have received. The first type of high impact patent is a hot patent. This is a patent that receives a high percentage of its citations from recently issued patents. The two criteria for hot patents are:

- Cited frequently by recent patents
- Recent citations represent a high percentage of total citations.

The current paper details calculations and potential as an M&AS tool.

Examples

Air Products

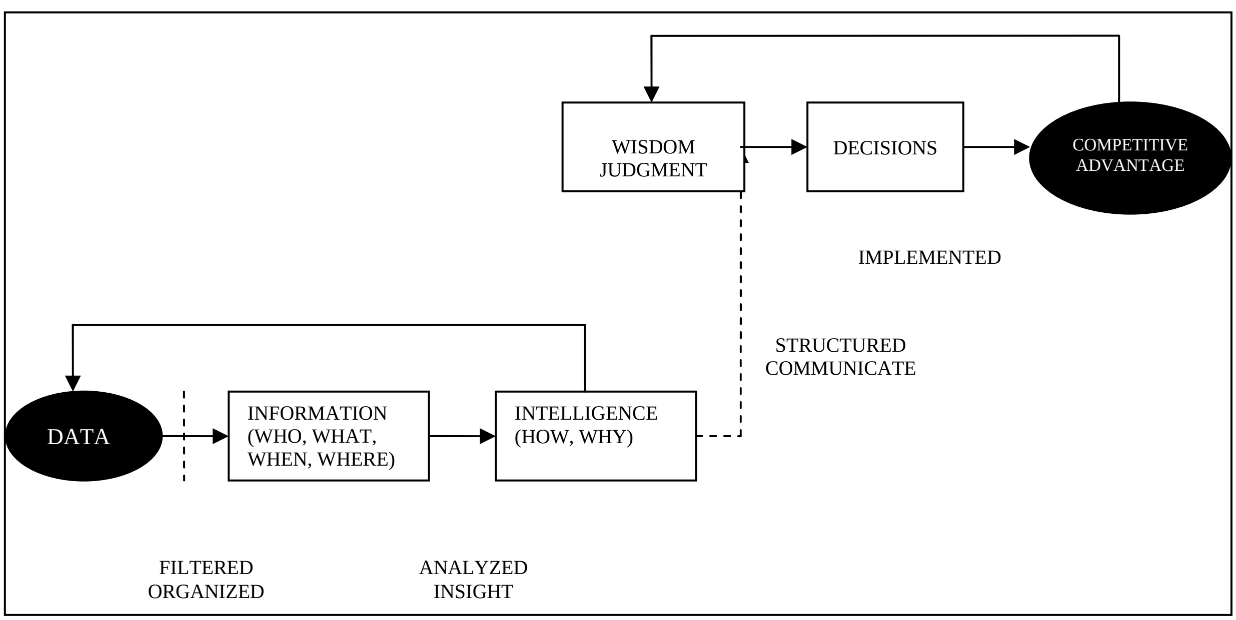
Air Products is a global company with products in gases, chemicals, equipment, and services (Brenner et al. 2005). Although the company is based in the U.S., half of its sales are outside the country. It employs about 20,000 people in 30 countries. This vast company is served by a staff of six people, who have jobs in what they call “business intelligence.”

This staff defines business intelligence as creating “knowledge and foreknowledge of the competitive environment to support decision making.” They place “primary emphasis on early warning of new developments, capabilities, and strategies of competitors and potential competitors.” They see several roles for technological intelligence in the company, including supporting decisions and strategic development and competitive evaluations. The staff maintains the company’s core expertise in information analysis. They can handle huge volumes of information and make sense of them, at levels that would overwhelm others in the company.

The Air Products intelligence staff use Figure 2.2 to describe what they do and how it relates to decision making in the company. They start by trying to determine “the facts,” which they filter and organize to be able to report what, when, and where a new technology is developing. They then analyze this information and add insight to begin to fill in how and why the development is happening. Once they know this, the information is ready to communicate into the company’s decision process. They make sure that at this point their “intelligence” is structured in a way that it can be communicated effectively to decision makers. The company’s leadership then adds wisdom and judgment to the “intelligence,” and the result in decisions, which hopefully result in competitive advantage for the company. Whether they do or not feeds information back into the judgment capacity of management, to shape future decisions.

Figure 2.2. Turning Intelligence into Advantage

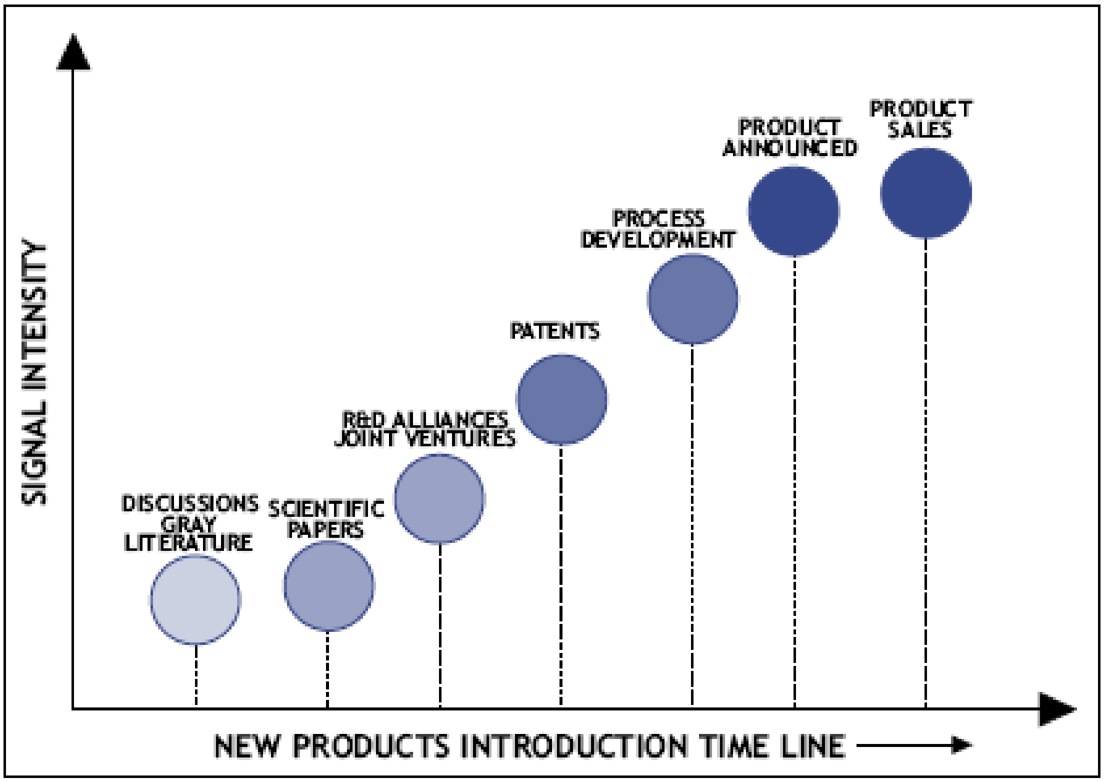
Source: Brenner et al. 2005



The Air Products business intelligence unit specializes in picking up early signals of new technologies being developed by competitors. They characterize the sources they use to do this in Figure 2.3. At the beginning of the process, the signals are very weak and are only picked up in discussions or unpublished literature. Publications in the open literature may come shortly afterwards, followed possibly by the announcement of alliances or joint ventures. They find in their business that patents are late signals, coming perhaps 3-4 years after the development starts, and not long before new products actually appear on the market. Clearly, the task of the business intelligence unit is to pick up signals as early as possible so that the company can take effective action.

Figure 2.3. Changing Signals.

Source: Brenner et al. 2005



The Air Products business intelligence staff cannot track every technology the company uses in its very diverse lines of business, so they put considerable effort into identifying potential users and pinpointing their needs. They use their expertise with information systems to help them in that task. They maintain an online system that users can access to create their own profiles of needs. About 2400 users are registered from around the company. Once potential users enter their profiles in this Experience Database, they receive updates from the business intelligence unit when new information becomes available. The intelligence group also adds user profiles. They actively interview people throughout the company about their needs for intelligence; these contacts usually result in gathering more in-depth information in an area and in more attention to the needs of that user in regular monitoring activity.

The intelligence unit has several forms for distributing the information it gathers. It sends out about 10-15 informational alerts a day and an additional 1-2 action alerts, with a higher level of urgency. They use an attached feedback form and other surveys to find out how useful their work is to users, and find that 80% find the action alerts useful, and about 30% actually take action on them. The unit also produces more extensive "intelligence backgrounders" at the rate of about 50 per year. They also maintain information analysis expertise for the company and facilitate processes of discussion around developments they have identified outside the company. They do not work alone, but instead maintain a "community of practice" consisting of others around the company trained in some of their analysis tools, who can help with more in-depth examination of particular issues of interest.

Procter & Gamble's Innovation Model: 'Connect and Develop'.

P&G's innovation model, which is based on the company's reliance on external R&D to leverage their own innovative capacity, is an interesting case in many respects. As Huston and Sakkab (2006) claim, when the company decided to shift in 2000 from its 'invent it ourselves' strategy to its 'connect and develop' model, consisting on the identification of promising ideas throughout the world for their application by their own existing capabilities, P&G started to create better and cheaper products, faster, adding value to the company's performance and value (Huston and Sakkab 2006). Currently, the company collaborates with suppliers, competitors, scientists, entrepreneurs, and others (connect), systematically scouring the world for proven technologies, packages, and products that P&G can improve, scale up, and market (develop), either on its own or in partnership with other companies.

According to the authors, thanks to P&G's 'open innovation' strategy the company now produces more than 35% of their innovations and billions of dollars in revenue. To do this, once a year the company creates a top ten consumer needs list for each of their business and one for the company overall. Examples given by the authors of the kind of items appearing in the company's list include needs such as "reduce wrinkles, improve skin texture and tone," "prevent or minimize the severity and duration of cold symptoms," "create softer paper products with lower lint and higher wet strength," etc. These needs lists are then developed into science problems to be solved. The problems are often spelled out in technology briefs and sent through the company's proprietary networks (technology entrepreneurs distributed around the world who combine mining of the scientific literature, patent databases, and other data sources with physical prospecting for ideas[3], and suppliers who, through a secure IT platform the company contacts and shares technology briefs), and open networks (such as NineSigma, InnoCentive,

[3] According to Huston & Sakkab (2006), the technology entrepreneurs work out of six connect-and-develop hubs, in China, India, Japan, Western Europe, Latin America, and the United States. Each hub focuses on finding products and technologies that, in a sense, are specialties of its region: The China hub, for example, looks in particular for new high-quality materials and cost innovations products that exploit China's unique ability to make things at low cost. The India hub seeks out local talent in the sciences to solve problems–in their manufacturing processes, for instance – using tools like computer modeling.

YourEncore, and Yet2.com, whose mission is to facilitated connections between companies that have science and technology problems with companies, universities, government and private labs, and consultants that can develop solutions).

P&G also identifies adjacencies – that is, new products or concepts that can help them take advantage of existing brand equity. As the authors report, they might, for instance, ask which baby care items – such as wipes and changing pads – are adjacent to our Pampers disposable diapers, and then seek out innovative emerging products or relevant technologies in those categories.

Finally, in some areas, they use what they call ‘technology game boards’ to evaluate how technology acquisition moves in one area might affect products in other categories. According to the authors, that helps them explore questions such as “Which of our key technologies do we want to strengthen?” “Which technologies do we want to acquire to help us better compete with rivals?” and “Of those that we already own, which do we want to license, sell, or codevelop further?” Allegedly, the answers provide an array of broad targets for their innovation searches and, tell them where they shouldn’t be looking.

Other Cases of Private Sector Monitoring and Alerting Systems and Services

Technology Intelligence and Technology Scouting exercises are performed internally at private organizations or by contract. Companies performing such exercises include Air Products and Chemicals, Procter and Gamble, Rohm & Haas, Kodak, DuPont, 3M, Novartis, Merck, Eastman, BASF, EcoLab, Ford, and Agfa, among others.

Outsourcing of some of these services for various public and private organizations are contracted out with firms such as Aurora WDC; Business Intelligence Services, a Thomson Business; Business Intelligence Source; C3i Consultants India Ltd.; Chapel Hill North Group; Cipher Systems; Comintell; Concurrent Technologies Corporation; Fletcher/CSI; Fuld & Company; Global Intelligence Alliance; Helicon Group; Hilty Moore & Associates LLC; I.S.I.S. - Integrated Strategic Information Services, Inc.; Mindshifts Group, The; Moreover Technologies; Novintel Inc.; Perpetual Strategist; Preservation Data; Proactive Worldwide; QL2 Software, Inc.; Rodenberg Tillman & Associates; Search Technology; Sharp Market Intelligence; SIS International; Synovate Business Consulting>

Technology Intelligence at the US Army

The Army Research Laboratory (ARL) is the Army’s corporate basic and applied research laboratory. It consists of the Army Research Office and six Directorates--Weapons and Materials, Sensors and Electron Devices, Human Research and Engineering, Computational and Information Sciences, Vehicle Technology, and Survivability and Lethality Analysis.

ARL focuses on maturing technologies for transition principally to the Research, Development, and Engineering Centers (RDECs), but also to other partners in the Army and the private sector. It relies on the US Army International Technology Centers (USAITCs) for the identification, acquisition, integration and delivery of foreign technology solutions to the warfighter.

Currently there are International Technology Centers (ITCs) in Canberra, Australia; Camp Zama, Japan; Ottawa, Canada; Bonn, Germany; Paris, France; London, United Kingdom; Buenos Aires, Argentina; Santiago, Chile, and Singapore. Their objectives is to i) facilitate US Army access to foreign technologies and materiel solutions found abroad; ii) provide US Army Science & Technology presence and expertise to address capability challenges faced by the US Program Manager and Program Executive Offices; iii) Identify foreign technology solutions for Current Force capability gaps and for Future Force potential; iv) drive Multinational Force Compatibility and Interoperability; and v) support senior level for as the US Army armaments liaisons

These ITCs conduct regional technology watch, using the International Science and Technology Investment Strategy as a guide on what technologies to pursue and where. As regional representatives, the Army ITCs seeks to anticipate U.S. technology requirements and initiate approaches to expanding contacts with foreign military R&D organizations, foreign commercial industry and foreign universities involved in S&T. Based on their discoveries, the centers offer recommendations to the US Army Research, Development and Engineering Command (RDECOM), its laboratories, and other Army organizations on potential opportunities for cooperative projects, commercial contracts, university studies, etc., that will leverage International S&T in support of Army transformation objectives. The Research Division has functional responsibility for the following disciplines: Aeronautics, Mechanical Engineering, Materials, Electronics, Computer Science, Chemistry, Biological Science, Physics, Environmental Science and Behavioral Science.

Center for Strategic Management and Studies, Brazil.

The Centro de Gestão e Estudos Estratégicos (CGEE) was created with the support of the Brazilian government as a non-for-profit organization aiming at promoting and accomplishing future studies and foresight in the field of science, technology and innovation, as well as the activities of evaluation of strategies and economic and social impacts of scientific and technological policies, programs and projects.

According to Fellows et al. (2005), inspired upon some concepts developed on Future studies , CGEE considers foresight as an activity that connects three different dimensions on the same process: thinking, debating and shaping the future (Fellows et al. 2005). As the authors posit, the structuring of communication channels and the process of coordination in different levels acknowledge the importance of the governance process that guarantee, claim the authors, the validation of technological opportunities identified during the process by the different stakeholders and be transformed into concrete actions by decision makers.

CGEE's approach also considers that many forms of analyzing future technology and its consequences coexist. Hence, a combination of techniques including technology intelligence, forecasting, roadmapping, assessment, and foresight are used. According to CGEE, the management of foresight exercises tries to follow the standard method consisting of definition of objectives, theme selection, implementation and decision making. A list of their studies appears in Appendix 1.

Office of Naval Research

The Office of Naval Research (ONR) promotes, coordinates, funds and executes the S&T programs of the U.S. Navy and Marine Corps. It provides advice to the Chief of Naval Operations and the Secretary of the Navy on technical issues, and works with industry to improve technology manufacturing processes.

According to the ONR's website, it utilizes a portfolio balanced between discovery and invention, that is, a 'technology push' set of initiatives, and delivery and exploitation, that is, a 'requirements pull' set of initiatives inspired on the Future Naval Capabilities Program –FNCs, which focuses on providing Enabling Capabilities (ECs) to close warfighting gaps.

The FNC program provides technology solutions by bundling S&T products that deliver a distinctly measurable improvement within a five-year time frame. The Technical Oversight Group approves the FNCs based on their contribution to closing a warfighting capability gap, rather than on individual products. Thirty-five ongoing ECs are dedicated to the FNCs.

ONR Programs are developed and executed nationally through universities, government laboratories, industry and nonprofit organizations. Collaborations with the international S&T community are promoted and developed through ONR Global, an ONR department comprised of several international field offices.

The U.S. Office of Naval Research Global seeks worldwide science & technology-based solutions to Naval challenges. ONR Global combines the expertise of over 40 scientists, technologists, and engineers with a physical presence on five continents. The main office is located in London, UK with current satellite offices in Tokyo, Japan; Singapore; Santiago, Chile; and soon Australia. ONR Global supports activities ranging from basic research to prototyping.

The ONR Global Science and Technology Division engages the international S&T community in i) naval architecture and shipbuilding (including electric warship); ii) communications, command and control, computer science and electronics, optics and radar; iii) human factors, knowledge-based and learning sciences; iv) atmospheric and space sciences, and oceanography, including underwater acoustics; v) materials science; vi) manufacturing Technologies; and vii) Biosciences.

The ONR Global S&T Division also encourages collaboration in emerging areas of S&T in diverse areas of scientific specialization. The staff consists of experienced generalists who are grounded in their own disciplines and also have the ability and stature to facilitate connectivity between the DON and the international arena. The staff uses their own interests and contacts supplemented by advanced data mining techniques and a country opportunities database to highlight areas of technology development.

ONR Global's main products are written reports which are published via the Internet; and assessments of the changing trends of world science and technology. A list of some of the exercises on technology watch done at the Office of Naval Research is presented in Appendix 2.

Patent Technology Monitoring Division (PTMD)

at the U.S. Patent and Trademark Office (USPTO)
(http://www.uspto.gov/web/offices/ac/ido/oeip/taf/tafp.html)

According to its website, the origin of the PTMD is ascribable to the USPTO's early recognition that the patent file embodies a unique and the most comprehensive assemblage of technological information as patent law requires for a full disclosure of invention. The USPTO has fulfilled its responsibility not only to preserve, maintain, and improve the patent file, but also to maximize its use for the greatest public benefit. It was as part of the effort to discharge this latter responsibility that the USPTO established the Office of Technology Assessment and Forecast (OTAF) in 1971. Although the work efforts of this organization have changed over time, much of its work continues to be performed by the PTMD that is positioned as part of the USPTO's Customer Information Services / Office of Electronic Information Products.

In its most general terms, a mission of the PTMD is to stimulate the use and enhance the usability of the patent file, and to assemble, analyze and make available meaningful data about the file. To carry out this mission, the USPTO has assembled the TAF master database covering all U.S. patents. Then, the PTMD uses the database to generate statistical reports profiling various characteristics of U.S. patents. Periodically, the PTMD also has produced general publications which examine patenting trends. Additionally, the TAF database is used to prepare custom data reports, tailored to individual needs. These reports, which are provided on a reasonable cost basis, subject to the availability of resources, are used by other government agencies and many private sector organizations. In sum, the PTMD can be said to have performed national technology monitoring by periodically issuing general statistics and miscellaneous reports that profile patenting activity. In this context, it is notable that some statistics garnered by the PTMD have shown up in the NSB's Science and Engineering Indicators series, the most recent series of which contains figures and tables on patent primarily from two sources, that is, the USPTO PTMD and ipIQ (formerly, CHI Research).

The PTMD has made many products and services, several of which are free while some others are available at reasonable cost. First of all, many PTMD general statistical reports and materials are available on the Internet, and some are also available by FTP. Those patent statistics reports are generated to be available for viewing as report breakouts by several important categories. The result is the following reports accessible on-line: Patenting by Type of Patent Document Report; Patenting by Geographic Origin; Patenting by Patenting Organization; Patenting by Inventor. Additionally, the reports are generated for viewing on historical and extended-year set statistics, and other miscellaneous reports. In addition to the above statistical reports available on its website, the PTMD has produced many other reports. A list of selected reports include the followings: Activity Index Report; Activity Index Report, Corporate Patenting; Activity Index Report, Utility Patent Applications; Activity Index Report, Corporate Utility Patent Applications; Patenting Trends in the United States; Patenting Trends in the United States, State Country Report.

More interestingly, the PTMD has produced many technology reports that provide a detailed profile of patent activity in a specific technology. A list of subject areas appears in Appendix 3. Finally, the PTMD usually generates its general statistical reports in March or April of each year to incorporate date through December of the previous year. Midyear updates may be generated for some PTMD reports with the update reports containing data through June. These update reports, if generated, are generally available in late July to early August. One exception is the "U.S. Patent Statistics Report", which is fully updated in May/June of each year. On the other hand, PTMD single year reports are usually generated in February of the following year. The "Patenting By Organization Report", however, is updated once per year in March/April.

Austrian Research Centers (ARC) Systems Research GmbH

(For ARC, see http://www.arcs.ac.at/home_en.html or http://www.arcs.ac.at/sitemap_en.html. For ARC Systems Research, see http://www.systemsresearch.ac.at/index.php?version=2&cid=59)

As Austria's largest center of applied research employing 850 employees, Austrian Research Centers (ARC) purports to combine the expertise of all major branches of the natural sciences and other scientific disciplines. According to its website, ARC is committed to interdisciplinary work for the benefit of its customers from business and public administration. ARC is composed of the ARC holding company and the other subsidiary corporate units. For administration purposes ARC is organized as a group under the ARC holding company named the ARC Group that is a limited liability company under the Austrian law. Its character seems somewhat unique as its shareholders are composed of the Republic of Austria and businesses with the share ratio of 50.46% to 49.54 respectively. And the business shareholders are from various sources such as not only industry but also electricity utilities, banks, insurance companies, and professional associations. The above characters seem to make ARC a somewhat unique entity posing a quasi-government institution.

However, the major components of ARC are its nine subsidiary companies that work under an assumption that modern research must follow an interdisciplinary and networked approach to obtain results that ensure both market success and optimum benefit for the public. Their principal missions are described generally as follow. First, they cooperate with researchers at universities, universities of applied sciences and other research institutions across the globe, especially within Europe. Also, Austria's major companies act as ARC's partners and shareholders. Together with them, ARC companies develop cutting-edge products and processes ranging fro design to industrial application. Second, ARC companies aims to serve specific needs of the public such as food inspection, pollutant measurement, and protection in the case of nuclear accidents. Third, they are to contribute to consolidating and extending Austria's position in the face of international competition.

Among the numerous ARC companies, of most interest to this project is ARC Systems Research GmbH that alleges to have technology monitoring as one of its innovation research focuses. ARC Systems Research is composed of four business units including Technology Management, Technology Policy, and Regional Studies. And the head of the Technology Policy business unit has been appointed chairman of the Scientific Steering Committee of ETEPS (European Techno-Economic Policy Support

Network), which is a consortium founded together with 18 core members in order to support the European Commission in policy issues. As one of nine subsidiaries of the ARC Group, its independent research is financed through funds made available by the Federal Ministry for Transport, Innovation and Technology and allocated by the ARC holding company. Also, its participation in the framework programs of the European Union as well as national and regional research funding programs further strengthens its funding base. Another interesting fact is that since the majority of its projects deal with interdisciplinary research, the projects are carried out in teams recruited from systems research scientists or in cooperation with other applied research institutions, universities and private research enterprises. Generally speaking, ARC Systems Research focuses on applied systems research that is about analyzing social, economic, and natural systems and intervening in these systems. Within its purported specialization in applied systems research, its works focus on issues of innovation and environmental research. Additionally, its mission as a research company is to enhance the understanding and performance of the Austrian innovation system, to support sustainable development in Austria, and to accompany Austria on its journey to a knowledge-based society.

More specifically on research by ARC Systems Research, its research concentrates on five research areas, among which one research area named "innovation research" is the most pertinent to us. In turn, the innovation research area currently has 4 research focuses including technology monitoring. The following is an enumeration of ARC Systems Research's research areas and focuses.

- **Innovation Research**
  - Systems Innovations
  - **Technology Monitoring**
  - Knowledge Management
  - Innovation Processes
- Conceptual Environmental Research
- Regional Research
- Complexity Research
- Foresight & Evaluation

ARC Systems Research engages in "technology monitoring" by conducting extensive bibliometric analyses of electronically-stored structured information of defined technology areas. According to what is revealed on its website, it thinks that technology monitoring is to identify technology pathways, R&TD (Research and Technology Development) strategies of companies and research institutions and other relevant information of defined technology areas. As such, ARC's technology monitoring is designed to answer the following questions.

- What technologies exist today and what technologies will be applied in the future?
- What materials and resources are used?
- What are the fields of application for different materials?
- What companies, institutions or individuals have the highest expertise in a specific topic?
- Who cooperates with whom on a regular baiss?

Especially, ARC Systems Research states that it specializes in shaping technology-oriented innovation processes in companies. For this purpose, it relies primarily on a method that it dubbed “bibliometric R&TD monitoring”. Thus, the company-focused solutions developed by ARC Systems Research consist of a series of bibliometric devices such as methodology, data-processing software, and procedure for designing a monitoring. As this method has its roots in the evaluation of research services in science and in the field of data mining, it deals with the formal and thematic evaluation of electronically stored information from literature and patent specifications. In addition to research literature and patents, its analyses have been conducted on information from press agencies, corporate databases and the internet. On top of these, expert knowledge is integrated by various methods such as scenario techniques, Delphi surveys, interviews or expert workshops. Although we were unable to access any substantive materials, the followings were introduced as its major projects on technology monitoring: Perspectives of satellite based navigation and communication; Strategies of automotive manufacturers in the field of hybrid vehicles; Security research – definition and agenda for Austria.

Finally, in addition and in relation to technology monitoring research, one thing is worth noting separately as apposite to our research interests. That is, ARC Systems Research has developed its own software for structuring and visualizing bibliometric data. According to its general description of the software named “Bib TechMon,” the bibliometric methods implemented in this software visualizes relationships of terms in a network structure, opening up a wide range of applications. The core idea of this instrument is to structure and visualize a large number of documents in map of knowledge, which presents different thematic elements while also allowing access to the original documents. The documents are available in a structured form so that keywords, authors, and citations can easily be extracted, presented and analyzed in a network. And the analysis of patent or literature citations was suggested as a classical application.

General lessons

Some general lessons can be drawn across the various examples. All the analyses are client-driven, with a focus defined in relation to a client need. Most of the analyses focus at the level of fairly specific technologies – either starting there or getting there. All use some combination of text-based information with expert knowledge.

CHAPTER THREE: OPTIONS FOR A NATIONAL MONITORING AND ALERTING SYSTEM

Based on this review of strategic intelligence efforts internationally, we envision a Korean national M&A system with the following characteristics:

- It would focus on the detailed information on research areas and technologies provided by sophisticated data mining and analysis techniques.
- It would be anchored by information on specific Korean research and technology competencies, as identified by those techniques.
- It would identify both threats and opportunities in strategic Korean research and technology areas.
- It would be a dynamic system, with regular updating of the analysis of Korean competencies and their place in global developments.

Within this general description, there are a number of ways that KISTI might develop the national M&A system. We describe a number of options here, each of which could be done individually or bundled into a larger effort.

Three levels of monitoring

Monitoring and alerting can be carried out at different levels of aggregation in any science and technology system. The most relevant levels in relation to emerging technologies are firms, industries, and the national level. At each level, the relevant public research portfolio can be assessed with regard to the technological needs of the unit being analyzed. Whether implemented top-down or bottom-up, the system would identify the key internal and external issues at each level, as well as the issues the next level should be aware of.

The three-level system we describe here assumes that part of the public research portfolio will be matched to industrial needs, through priority-setting and collaborative research. That part can be evaluated in relation to the technological profiles of Korean firms and industries. The system also assumes, however, that a part of the public research agenda will not be matched in this way, but rather directed to addressing public goals (e.g., energy) and to basic research. Basic research over a broad spectrum of fields (a characteristic we call "balance" below) maintains flexibility for the system and helps to monitor external developments. This kind of research portfolio is an important risk management technique for the national research and development portfolio, and the M&S system can provide information to help evaluate whether it is performing these functions. It also provides information that helps to benchmark those research efforts, to know whether they are at or near the international research fronts, a characteristic we refer to below as "competitiveness."

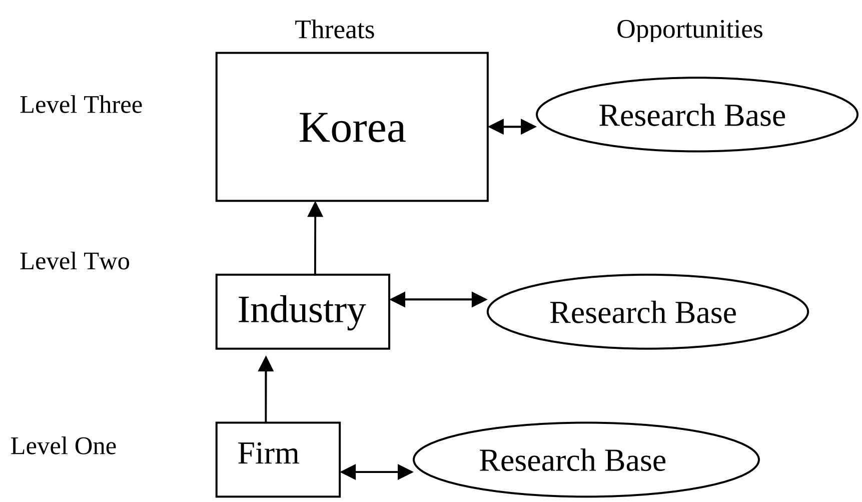
The *national* level of the M&A system provides the overview of Korean research and technology in international context. Some of the questions it would address are directed to industries and technologies: Are there broad trends in technology that will affect several Korean industries? Are new opportunities opening up that we should try to exploit or at least monitor? This level of the system would monitor for potential new industries, major technologies emerging outside Korea. Other questions would be directed to the country's human resources and scientific capacity: Is our public research base balanced and competitive? Is our science and engineering workforce flexible, responsive? Answers to these questions would allow policy makers to shift training and research portfolios to maintain capacity for Korean industry to adjust.

The system could include monitoring at the *industry* level, since technological changes that affect one firm will probably affect many, in waves of change. By themselves, one at a time, firms might not recognize these waves. In addition, the response may require coordinated action. Industry-level monitoring would therefore watch for trends in changes across firms in an industry; monitor that industry outside Korea; and monitor competitive status of relevant public research base, as described above. This information would allow the industry to respond with sector-wide policies or programs, e.g., redirecting training or public research efforts.

Finally, monitoring and alerting could be carried out at the level of individual firms. Firms are uniquely well positioned to monitor their technical environments for potential radical change. Strategic intelligence tools can help them to do that, but cannot do it for them. While a national institution like KISTI would not be able to do all the detailed analysis that is necessary, KISTI could provide training in competitive intelligence as part of a network of analysts, who would then contribute information on their firms to be aggregated upwards through the system. Like Air Products, each firm might want to identify the company's technology profile, follow specific technologies, identifying competitors and monitoring their technologies, go into depth where needed, and report to management. In addition, as part of a national network, the firms would report some non-proprietary information is relevant to the whole industry into the industry level analysis.

The overall structure of such a system would look like Figure 3.1, and could be implemented either top-down or bottom-up.

Figure 3.1. Three-level system structure



Options for Analysis

National inventory

In order to examine Korean research and technology dynamically in relation to global developments, it will be necessary to collect baseline information. The development of the national M&A system might therefore begin with an inventory of the publication and patent profiles of Korean research institutions and R&D-performing firms. National indicators data should give an indication of how many of these there are, and the unit that compiles them may be able to provide a list. This could then be compared with the addresses associated with publications in the Web of Science, patents in Derwent's World Patent Index, and other data bases. Korea's profile in terms of research and technology competencies could be derived from this data using keyword profiles as a first indicator. The keyword profiles could be presented by institution group or by industry. Keyword mapping might show some connections between research institutions and R&D performing industrial firms.

Competitor analysis

The keyword profiles developed in the national inventory could be used to identify institutions and countries that are doing research or patenting technology in the same areas as Korea's institutions. For R&D-performing industry, this analysis might be done by industry group. Having identified the institutions, the same data bases could then be used to characterize what the competitors are publishing or patenting. These "neighboring" research topics or technologies might be either threats or opportunities for Korean institutions. The leadership of those institutions would need to examine and discuss the results in order to determine whether either or these is the case. Competitor analysis also allows for benchmarking, that is, comparing the performance of Korean institutions with others working in similar areas, on measures such as network centrality in keyword networks or citation rates.

Participation in emerging research areas

In the existing data bases that identify the research fronts of science, emerging areas can be identified with several indicators, for example, low average age of cited documents, first appearance of the research front, or some combination of the two. Korean participation in the emerging research fronts can be calculated and compared with levels of Korean participation in all research fronts and in the whole underlying data base.

More important than the overall figure for participation is the identification of specific areas where Korean researchers are active and not active. How do these compare with the core research competencies identified in the keyword analysis in the baseline inventory? Are Korean researchers active in many areas where they are not among the leaders? Do some areas stand out as places where Korean researchers are leading the world? Are Korean researchers among the leaders in strategic research areas, that is, those that are important to achieving national goals, solving societal problems, or contributing to economic growth?

In addition, it will be important to identify major emerging areas where Korean researchers are not active. These are areas of potential threat or opportunity, which again, bear examination by the country's S&T leadership as priority areas for future investment.

Participation in emerging technology areas

A parallel analysis to the existing research front data could be done for patents, as indicators of emerging patent technology areas; or rapid growth in existing patent categories could be used. In either case, an analysis of Korean participation in emerging technology areas could follow the pattern described above for research areas. A first step is to sort emerging areas from others, using indicators of newness and rapid growth.

A second step is to identify which of the emerging areas have Korean participation and by which institutions. Are Korean patent holders among the leaders in these fields, as indicated by when they filed patents? Do these areas match the core technology competencies for Korea identified through the keyword profiling in the national inventory?

It may be of interest to examine whether Korean patenting is happening in areas with strong connections to a science base, and where that science base is located. An indicator of this relationship is citations from patents to the scientific literature.

Finally, it will be important to examine the emerging technology areas where Koreans do not participate in patenting. Areas where Korea does R&D but does not patent might present vulnerabilities or opportunities. Alternatively, if they are in areas irrelevant to the Korean economy, they may simply be neutral. However, if a major area of patenting is developing outside the Korean economy, policymakers may want to be aware of its existence and take this into account in long term planning.

Knowledge flows

The contemporary literature on innovation uses the concept of national innovation system, which was developed in part by Dr. Linsoo Kim, a Korean economist. A national innovation system consists of actors, their relationships, and the institutional environment within which they operate. Knowledge flows among innovating firms and research institutions is considered an important vital process for an innovation system, since it allows learning which stimulates new ideas. It also allows institutions to share information about their competitive environments and respond appropriately.

The national M&A system could monitor some basic indicators of knowledge flows between the institutions of the Korean NIS. Co-authorships and common patenting are two such indicators, readily available from the data the national M&A system will use. Citations between institutions are another indicator of knowledge flows within the system. Some examination of international collaborations may also be useful as part of this analysis. Each indicator could be examined specifically in relation to emerging research and technology areas identified as interesting in the previous steps.

Options for KISTI Roles

KISTI has several options for the role it would take in doing any or all of this analysis, including the following:

Issue regular reports

KISTI could produce regular reports from the M&A exercise, as national S&T indicator efforts do. If all the analysis above were done, the report would include nested information: Korea's place on the global map, the portion of that that referred to specific institutional groups or industry sectors, specific emerging research or technology areas, etc. An appropriate form for providing this information therefore might be an interactive web site that would allow drilling down in the structure, rather than a printed report.

Facilitate national discussion

It is clear from the international experience reported in Chapter Two that the results of the analyses described above will not translate directly into national policy options. People familiar with both the areas in question and the national S&T policy discussions will need to review the results, debate their implications, and make recommendations to the appropriate ministries of government, whether that is the Ministry of Science and Technology (MOST) or a sectoral ministry, such as Health, Environment, or Industry. KISTI could work cooperatively with MOST in facilitating that discussion. KISTI's in-depth understanding of the data and analyses themselves would be essential to the process, and MOST's position in national policy making would give the appropriate importance to the process.

Lead a network for M&A analysis

The kinds of analyses outlined above depend on developing routines of several sorts, possibly including clustering patent data, calculating measures of emergence, and cleaning and matching Korean addresses to international data bases. KISTI's information specialists are particularly well suited to supervise these algorithmic tasks. However, the analysis of results in specific strategic research or technology areas might fruitfully be shared with specialists in the research areas and industries in question. KISTI might therefore offer to lead a network of analysts drawn from across government and perhaps industry organizations as well. KISTI would train the members of the network and provide the data, but the members would write technical analyses in the various areas covered by the national data and supplement that broad analysis with more detailed looks at specific areas. Having these network members located in ministries and industry associations would make in-depth discussion within those areas more likely. Stimulating that discussion would be a goal of the network.

Train analysts in individual organizations

The expertise in strategic intelligence that would go into the national M&A system would also benefit individual research institutions and R&D-performing industrial firms in Korea, moving the country towards a "strategic intelligence culture." KISTI could provide training and consultancy in this area. As the expertise spreads, the analysis of Korean core competences, competitive environments, threats and opportunities, might be able to be constructed bottom-up from research organizations and firms. At the least, issues that are identified at that level could inform the discussion of the broader results.

Build expertise for communicating results

A key lesson from the international experience with strategic intelligence is that packaging and communicating results is an important part of the process. KISTI could establish itself as a center for expertise in this area. Sophisticated visualization techniques are becoming more and more prominent in the interface between strategic intelligence analysts and the decision makers they support.[4] Visualization of large amounts of data is computationally intense. As the computational leader in Korean research and development, KISTI is thus well suited to developing appropriate tools.

Conclusions

A national M&A system is an ambitious project. The data on national institutions and emerging research and technology areas must be filtered and analyzed to become intelligence. Data-based intelligence must then be communicated and discussed in the decision context to turn into competitive advantage for Korea. However, key techniques and approaches to accomplish these objectives already exist. It remains for KISTI, and Korea, to put them together into a unique national resource.

[4] For example, see www.mapofscience.com.

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Appendices

Appendix 1: S,T&I Forecasting at CGEE[5] (Original in Portuguese)

- Innovation and production in the chemicals sector (2004)
- Research, cutting edge areas and postgraduate education in chemistry (2004)
- Training a chemist: challenges and needs. (2004)
- Current situation, perspectives and investment needs in chemistry (2004)
- Competitiveness and innovation patterns in drugs and medicines (2004)
- Climate and water resources (2003)
- Water products and equipment (2003)
- Technological forecast of water resources (2003)
- Subsoil water quality (2003)
- Superficial water quality (2003)
- Water use in rural areas (2003)
- Water sanitation (2003)
- Public Policy subsidies in the health sector – innovation, international look: scientific articles and medicines (2003)
- Public Policy subsidies in the health sector – innovation, national look: researchers and firms (2003).
- State of the art and trends in technologies for energy. (2003)
- Biodiesel Agribusiness and opportunities for Brazil. (2002)
- Action Scenarios for public R&D and innovation organizations in the Brazilian agribusiness 2002-2012 (2002)
- State of the art of the Brazilian mineral technologies. (2002)
- Opportunity identification, challenges and problems facing the electric energy sector. The Brazilian northeast region. (2002)
- Opportunity identification, challenges and problems facing the electric energy sector. The Brazilian northern region. (2002)
- Competences mapping and R&D infrastructure in energy in the Brazilian northeast region. (2002)
- Competences mapping and R&D infrastructure in energy in the Brazilian northeast region.(2002)
- Electric energy management based on biomass in Brazil: current situation, opportunities, and development. (2001)

[5] For a complete list and access to the documents see http://www.cgee.org.br/atividades/index.php?a=1

Appendix 2: Text Mining at ONR[6]

"Systematic Acceleration of Radical Discovery and Innovation in Science and Technology ". 2006
A systematic approach to bridging unconnected disciplines and accelerating potentially radical discovery and innovation (based wholly or partially on text mining procedures) is presented. Potential advantages of using these literature-assisted and literature-based approaches include more radically innovative science and technology (S&T), improved global leveraging of S&T, improved coordination with domestic S&T sponsoring agencies, and technical journals acting more proactively to stimulate radical discovery and innovation. Additionally, these literature-based or literature-assisted approaches could offer S&T investors better insight into the potential of cutting-edge technologies.

"The Structure and Infrastructure of the Global Nanotechnology Literature" Journal of Nanoparticle Research. Springer Science. 2006. Volume 8. Issue 1
Text mining is the extraction of useful information from large volumes of text. A text mining analysis of the global open nanotechnology literature was performed. Records from the Science Citation Index/ Social Science Citation Index (SCI) were analyzed to provide the infrastructure of the global nanotechnology literature (prolific authors/ journals/ institutions/ countries, most cited authors/ papers/ journals) and the thematic structure (taxonomy) of the global nanotechnology literature, from a science perspective. Records from the Engineering Compendex (EC) were analyzed to provide a taxonomy from a technology perspective.

"Science and Technology Text Mining: Wireless LANs".
A study was performed to identify the structure and infrastructure of the Wireless LANs literature. An extensive query was developed to retrieve the Wireless LANs research literature, as represented in the Science Citation Index, for different time frames. For this retrieved literature, bibliometrics (counting of papers, citations, etc.) was performed to generate the infrastructure (e.g., prolific authors, Centers of Excellence) of the Wireless LANs literature, and computational linguistics (grouping of phrases, similar documents) was performed to generate the technical structure (pervasive technical themes, relationships among themes) of the Wireless LANs literature. Included in the bibliometrics results was identification of the seminal documents of the Wireless LANs literature.

"Science and Technology Text Mining: Mexico Core Competencies".
The structure and infrastructure of the Mexican technical literature was determined. A representative database of technical articles was extracted from the Science Citation Index for the year 2002, with each article containing at least one author with a Mexican address. Many different manual and statistical clustering methods were used to identify

[6] For a complete list and access to the documents see http://www.onr.navy.mil/sci_tech/33/332/techno_watch_publications_textmine.asp

the structure of the technical literature (especially the science and technology core competencies), and to evaluate the strengths and weaknesses of each technique. One of the pervasive technical topics identified from the clustering, Thin Films research, was analyzed further using bibliometrics, in order to identify the infrastructure of this technology.

"The Structure and Infrastructure of the Finnish Research Literature" Technology Analysis and Strategic Management. Vol. 18. 2006.
A representative database of technical articles was extracted from the Science Citation Index for the years 2003-2004, with each article containing at least one author with a Finnish address. Document clustering was used to identify the main technical themes (core competencies) of Finnish research. Four of the pervasive technical topics identified from the clustering (Wireless Networks and Mobile Communication, Signal Processing, Materials Science and Engineering, Chemistry) were analyzed further using bibliometrics, in order to identify the infrastructure of these research areas. Finally, the citation performance of Finnish research in the four pervasive technical topics above, and in other technical topics obtained by text phrase analysis, was compared to that of two Scandanavian countries with similar populations and GDPs: Norway and Denmark.

"The Structure and Infrastructure of Chinese Science and Technology" DTIC Technical Report Number ADA443315. (http://www.dtic.mil/). Defense Technical Information Center. Fort Belvoir, VA. 2006.
This report identifies and analyzes the science and technology core competencies of China. In addition to identification of the technical structure and infrastructure of the Chinese science and technology literature, two unique approaches were developed to compare characteristics of China's science and technology output with that of other countries. First, a novel method was used to compare the impact/ quality of all of China's research with that of two other countries, India and Australia. Second, a unique approach was used to compare China's research investment emphases/ strategy relative to that of the USA.

"Bilateral Asymmetry Prediction". Medical Hypotheses. In Press.
Presents a novel literature-based approach for identifying asymmetries in physical, engineering, and life science systems.

"Power Source Roadmaps Using Database Tomography and Bibliometrics". Submitted for Publication.
Presents the technical infrastructure and thrusts of electric power sources, converters, and storage systems.

"Electrochemical Power Source Roadmaps using Bibliometrics and Database Tomography". Journal of Power Sources. 110:1. 163-176. 2002.
Presents the technical infrastructure and technical thrusts of the Electrochemical Power discipline.

“A Chemistry Field in Search of Applications: Statistical Analysis of U. S. Fullerene Patents”. Journal of Chemical Information and Computer Science. 42:5. 1011-1015. 2002.
Analysis of bibliometrics aspects of fullerenes patent literature, and relation to bibliometrics of fullerenes research literature.

“Biowarfare Agent Prediction”. Homeland Defense Journal. 1:4. 1-1. 2002.
Describes a literature-based approach for predicting biowarfare agents.

“Electrochemical Power: Military Requirements and Literature Structure.” Academic and Applied Research in Military Science. Invited/ Submitted for Publication.
Describes military requirements for Electrochemical Power, and relation to technical literature structure.

"The Extraction of Useful Information from the BioMedical Literature". Academic Medicine. 76:12. December 2001.
Describes the use of advanced information retrieval, within the context of text mining, for extracting useful technical and infrastructure information from the biomedical literature.

"Predicting Biowarfare Agents Takes on Priority". The Scientist. 26 November 2001.
Describes the value of literature-based discovery (a component of text mining) for predicting potential biowarfare agents. Emphasizes the need for developing a national text mining capability to overcome the literature fragmentation from over-specialization.

"Surface Hydrodynamics Roadmaps Using Bibliometrics and Database Tomography".
An application of Database Tomography to surface hydrodynamics papers in the peer-reviewed published S&T literature. One objective is to ascertain whether surface hydrodynamics results and insights from many different disciplines can be of use in improving ship hydrodynamics.

"Database Tomography Applied to an Aircraft Science and Technology Investment Strategy". Journal of Aircraft, 37:4, July-August 2000.
An application of Database Tomography to Aircraft papers in the peer-reviewed published S&T literature. Contains the first example of estimating global levels of emphasis for technology sub-disciplines.

“Database Tomography Applied to an Aircraft Science and Technology Investment Strategy”, TR NAWCAD PAX/RTR-2000/84, Naval Air Warfare Center, Aircraft Division, Patuxent River, MD.
The full report on the Aircraft text mining study.

"Database Tomography for Technical Intelligence: A Roadmap of the Near-Earth Space Science and Technology Literature", Information Processing and Management, 34:1, 1998.
An application of Database Tomography to utilization of near-earth space papers in the peer-reviewed published S&T literature.

Appendix 3: Patent Analysis and Monitoring at the USPTO

Some reports are updated on a fairly regular basis while other reports are updated less frequently. Individual reports are available for the following subject areas with the date of the most recent available report being indicated in parentheses.

- Acid Rain (04/93)
- AIDS; Patents Relating to (02/94)
- Biotechnology, Patent Examining Areas 1630-1660 (12/04)
- Biotech Healthcare (12/97)
- Biotech Pharmaceuticals (12/97)
- Ceramics (06/93)
- Chemical/Electrical/Mechanical Disciplines (3 separate reports) (12/04) (these 3 reports are also available on the web)
- Coherent Light Generators, Class 372 (12/98)
- Data Processing: Document Processing- Class 707, Subclasses 500-542 (12/99)
- Data Processing: Financial, Business Practice, Management, or Cost/Price Determination - Class 705 (12/03)
- Drug, Bio-Affecting and Body Treating Compositions (Pharmaceuticals approximation) (12/01)
- Electrical Computers and Digital Processing Systems and Data Processing Systems - Classes 700-713, 716, 717 (6/2003)
- Enzyme Technology (12/97)
- Food or Edible Material: Processes, Compositions, and Products- Class 426 (12/94)
- Genetic Engineering (12/97)
- Hazardous or Toxic Waste Destruction or Containment - Class 588 (12/94)
- Immunology (12/97)
- Internal Combustion Engines (12/95)
- Internet-Related Patents (12/04)
- Internet Patents Relating To: Data Processing: Financial, Business Practice, Management, or Cost/Price Determination - Class 705 (12/02)
- Iron and Steel (06/93)
- Jet Engines (12/87)
- Machine Tools - Metal Working (04/93)
- Medical Devices (12/2004)
- Molecular Biology and Microbiology (12/00)
- Multicellular Organisms and Unmodified Parts Thereof - Class 800 (12/00)
- Multicellular Organisms and Unmodified Parts Thereof (Plant, Seedling, or Plant Part) - Class 800, Subclasses 260-323.3 (12/00)

- Needlestick Injury Prevention (12/99)
- Nuclear Energy (12/90)
- Optical Waveguides, Class 385 (12/98)
- Organic Compounds (04/93)
- Patents with Nucleotide and Amino Acid Sequence Data in Computer Readable Form (12/00)
- Plants, Class PLT and 800/200-255 (12/99)
- Robots - Class 901 (06/93)
- Semiconductor Devices and Manufacture (12/2004)
- Superconductors (12/94)
- Telecommunications (12/2004)